with the governments and industries of developing countries.

In conclusion, if the targets proposed by the IWP for 1985 are met, calorie and protein supplies and those of most other nutrients will cover physiological requirements. However, unless a serious effort is made by governments to reduce the inequalities of distribution within countries, the problem of undernourishment and malnutrition will not be entirely solved. There will remain some black spots on the map of the world, but assuming the IWP targets are reached, international efforts could be narrowed down and effective food aid could be given to a few countries containing only a small fraction of the world's population.

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DISCUSSION

Miss Olga Uvarov (*Glaxo Laboratories Ltd*) asked whether, in view of the increasing necessity to produce more protein, FAO had studied the developing techniques for planned breeding of animals – for example, œstrus synchronization and artificial insemination in different species.

Dr Nicol said that agriculture as understood by FAO covered the whole gamut of food production including animal husbandry, animal health, fisheries, and, of course forestry. In reply to the more specific question as to animal breeding, new techniques were being continually studied, and as much help as possible was given to member governments through projects developed and financed by the United Nations Special Fund. Most of the animal health and production people considered the extent of this financial aid to be dismally inadequate. FAO had no research resources of its own with which to supplement this.

Miss Uvarov thought this was one of the areas in which one could look for increased production.

Prospects for the Control of Infectious Disease

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In considering available and conceivable measures for their control, transmissible diseases can usefully be classified, first, by the types of host responsible for their maintenance in nature (Smith 1964) and for their transmission to man and, secondly, by their routes of transmission. However, their full understanding (and therefore their most effective control) demands appreciation of the relationships between the parasite and its hosts, and between them and their environment: quite small changes in any of these can have dramatic effects on the spread of disease. Enough knowledge already exists to control or to devise means for the control of a good many transmissible diseases of which the more important and particularly the more lethal have been largely eliminated from the more developed countries. Similar achievements are, however, impossible in many developing countries, not only because adequate means have not yet been found for the control of many of their more important diseases, but also because they are unable to exploit existing knowledge. Not only are these countries very short of resources in money and trained manpower, but their poor purchasing power inhibits the commercial development of modern drugs, vaccines, &c., for their use.

The essential prerequisite of all good public health measures is that careful estimates should be made of their advantages and disadvantages, for both the individual and the community, and that they should be implemented only when there is a significant balance of advantage. In general this ethic has been a sound basis for decision in most past situations in the developed world although, as we contemplate the control of milder diseases, quite different considerations such as the convenience or productivity of industry are being brought into these assessments. Although in developed countries, such considerations can reasonably be used to increase the balance in favour of the use, for example, of a vaccine, they should not be used to convert an adverse to a favourable balance. However, the developing countries have to take much more of an economic standpoint in assessing measures for disease control: the community must be considered rather than the individual, and because improvements in health often depend as much or more on improvements in the general standard of living, health measures must be balanced in economic terms against such alter-

natives as improved housing, food production or education. In addition, logical decisions ought to be made about how best to spend relatively limited medical and health resources to tackle a much too large and complex disease situation. But the comparative information on which such logical decisions might be based does not exist, and there is an urgent need for research to provide methods whereby realistic and comparable estimates could be obtained of the costs of controlling *and* of *not* controlling various diseases so that the best use can be made of available resources. When any control measure (e.g. insecticides, forest clearance) will involve widespread interference in nature, account must also be taken of the 'cost' of any long-term ecological and other consequences. Lacking a logical basis for priorities, most developing countries are forced to spread their inadequate resources thinly over the whole field of disease so that progress with any particular problem is often too little or too slow. Establishing priorities within medical and health expenditure is very difficult (and often impossible) even in the more developed countries but methods which would help in logical decision making are a crying need in developing countries and also for those who give overseas aid to them.

MAINTENANCE HOSTS

Infections or infestations can be divided into four main classes on the basis of the types of hosts which maintain them in nature: those maintained by man alone, those maintained by man together with an invertebrate intermediate host (e.g. mosquito, snail), and those maintained by other vertebrate species with or without invertebrate intermediate hosts (zoonoses). The rate of spread from host to host depends on many factors of which some of the more important are shown in Table 1. Because of the potential mutability and adaptability of rapidly multiplying parasites, control measures should be directed against as many of these factors as may be practicable. In general, the two main host factors are the frequency of 'effective contact' and the proportion of the host population which is susceptible to infection. Effective contact is the compound of the first six factors in Table 1 and defines the conditions in which there is a high probability that infection will be successfully transmitted from an infective to a susceptible host: e.g. sufficient proximity between hosts in the right environmental conditions for a respiratory disease, or a sufficient population of susceptible mosquitoes biting man in the case of say, urban yellow fever. The proportion of vertebrate hosts susceptible is influenced by previous infection with the same or a closely related parasite, by their reproduction rate, and by population movements into or out of the infected area, but most of all by vaccination.

Table 1
Some important factors in the rate of spread of infections and infestations

	Influenced by characteristics of:			
Factors	*Man*	*Other vertebrates*	*Invertebrates*	*Parasites*
Duration of incubation periods	+	+	+	+
Duration of infectivity	+	+	+	+
Stability outside hosts	-	-	-	+
Climate	+	+	+	+
Microclimate	+	+	+	-
Behaviour	+	+	+	+
Host susceptibility	+	+	+	-

Infections Maintained by Man

The main transmission routes are respiratory (droplet, aerosol), intestinal (hand to hand to mouth, water- or food-borne), or direct contact (venereal is perhaps the most important today).

The ease with which respiratory infections (e.g. influenza, common cold) spread even in highly developed communities suggests that measures designed to reduce effective contact are unlikely to be very successful, although reduction in overcrowding and better ventilation within buildings and other places where people congregate ought to help. As an example, however, the rapid spread of an organism so delicate as the meningococcus among American military recruits in modern barracks (Artenstein *et al.* 1967) offers little hope of controlling its spread in the great epidemic meningitis belt south of the Sahara by feasible improvements in housing. Thus vaccination seems to hold most hope in the control of diseases transmitted by the respiratory route (Dudgeon 1969*a*, Kaplan 1969, Rees 1969, Tyrrell 1969) and some highly effective vaccines already exist and are in use (e.g. against smallpox, tuberculosis, measles). Some respiratory diseases present special difficulty from the vaccine standpoint either because of diversity among their causative agents (common cold) or because of periodic antigenic changes in them (influenza): as regards feasibility, however, the former is perhaps largely an economic and logistic problem and the latter has been at least partially overcome by international surveillance of new virus strains. Although other forms of prophylaxis such as chemoprophylaxis or interferon may be valuable on a limited scale and over a short period, control of acute respiratory infections appears to lie with vaccination and there is little doubt that, in most instances, provided the causative organism is known and can be satisfactorily grown, an effective and

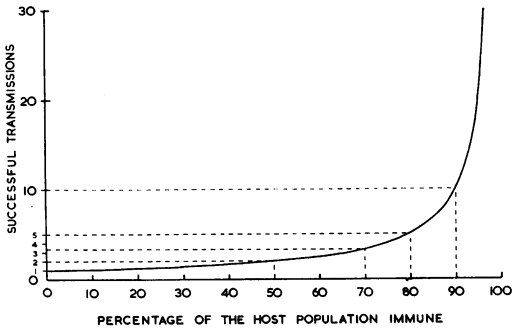

Fig 1 *Number of successful transmissions per infective individual if whole population susceptible*

acceptable vaccine could be made if the necessary expenditure of money and effort could be justified by the severity and/or frequency of the relevant disease. In each case there must be reasonable confidence not only that use of the vaccine would confer greater (and worth-while) benefit than harm, but secondarily that the cost of its development, production and deployment could be justified by its potential benefits. Effective control means reducing the proportion of susceptibles below some critical level characteristic of the infectivity of the organism in question (Fig 1). The 'infectivity' of a particular infection in a particular community can conveniently be expressed as the average number of successful transmissions which occur from each infective individual. This cannot be estimated accurately in human disease but some idea can be obtained from the proportion of susceptibles remaining when an epidemic ceases. Thus Macnamara (1955) found that urban yellow fever epidemics ceased when 65–48% of the population had become immune. This suggests that in this situation the average number of successful transmissions was between 2 and 3 per infective individual (Smith 1964). However, if virtual absence of the disease is to be maintained, the proportion of susceptibles must then be kept below the critical level until there is no risk of reintroduction of the infection which, in these days of intensive travel, may well be until world eradication has been achieved – and this may be for ever in some cases. If therefore the requirement is to maintain immunity throughout life, and unless very long-acting vaccines are available, consideration must be given to the possible hazards of many repeated doses of a vaccine which although quite acceptable for use in a few doses, may not be suitable for many.

In infections where carriers (e.g. meningococci, typhoid) or chronically infective diseases occur (tuberculosis) these have to be tackled by chemotherapy and other measures, or a lower level of control accepted. The World Health Organization (1967) estimated that there were probably 15 to 20 million infective cases of tuberculosis in the world and that the disease causes two to three million deaths a year. More than 80% of this disease is in the developing countries.

A special problem is presented by epidemic infections which occur very early in life: maternally derived antibody may not only interfere with effective immunization but may also (respiratory syncytial virus) contribute to the pathogenesis of the disease (Chanock *et al.* 1967, Gardner *et al.* 1970). In the same general context certain vaccines have been shown to aggravate the disease following subsequent infection, e.g. measles (Fulginiti *et al.* 1967).

The first line for an attack on fæcally transmitted diseases is improvement of general hygiene, but high standards imply a relatively prosperous standard of living. Good hygiene alone has largely eliminated these diseases from developed countries apart from small outbreaks due to carriers (typhoid, virus hepatitis) and bad hygiene, and apart from those (e.g. poliomyelitis) caused by an organism which survives particularly well outside the body and where transmission is largely between small children. Good hygiene supplemented by vaccination has, however, been highly effective in controlling poliomyelitis (Beale 1969). In many developing countries important fæcally transmitted diseases (hepatitis, cholera, amœbiasis, ankylostomiasis) remain rife and although when a cheap and effective method of vaccination is available (poliomyelitis) a good measure of control can be achieved, this class of infection is unlikely to diminish dramatically as a whole except in response to a marked increase in general living standards and successful education in more hygienic behaviour. The recent change from endemic to epidemic poliomyelitis among children in some tropical cities is probably attributable to the increase of susceptibles resulting from a rising birth rate and falling neonatal and infant mortalities. Morley's (1963) figures for a Nigerian village (Table 2) provide a basis for demonstrating the effect of falling mortality. Table 3 shows the

Table 2
Mortality in children in a Nigerian village before 1957 and in 1962 (Morley 1963)

	Before 1957	*1962*	*% decrease*
Stillbirths ●	41	38	7
Neonatal deaths ■	78	20	74
Deaths in 1st year ■	295	72	76
Deaths 1–4 years ■	277	43	84

● per 1,000 births
■ per 1,000 live births

Table 3

Expected numbers of susceptibles per 1,000 births based on figures from a Nigerian village (Morley 1963; Table 2)

Assumed annual infection rate	*Age (years)*	*Conditions prevailing*		
		Before 1957	*In 1962*	*Percentage increase*
5%	1	640	870	37
	2	500	810	63
	3	390	760	94
	4	310	710	130
	Average●	440	790	78
20%	1	640	870	37
	2	420	680	63
	3	280	540	94
	4	180	420	130
	Average●	340	610	78
50%	1	640	870	37
	2	260	430	63
	3	110	210	94
	4	45	105	130
	Average●	170	300	78

● Geometric mean showing the proportion of susceptible children under 5 years of age in the population

expected effects if the conditions before 1957 or in 1962 persisted for five years. The proportional increase in susceptibles is independent of infection rate although the absolute numbers depend on it. Such changes in the proportion of susceptibles (nearly two-fold in this case) will be important in increasing the intensity of transmission of any infection maintained by man. Research is required to determine the danger points in this widespread process but an essential prerequisite is the development of adequate vital statistics in developing countries.

The position of diseases spread by direct contact is very similar. Of these diseases, although it may also be transmitted in other ways, leprosy, affecting more than 10 million people mainly in developing countries (World Health Organization 1961) is perhaps the most important. Control must depend on a combination of treatment and vaccination and although results of the use of BCG vaccine are conflicting, there is encouraging evidence that it may be effective particularly against infection in childhood (Rees 1969). Diminution of effective contact is more efficiently achieved (and at less real and social 'cost') by treatment than by prolonged isolation.

In some areas, nonvenereal treponematoses such as yaws have been very successfully controlled by mass penicillin treatment and the same approach might work against the venereal diseases. But yaws was a relatively local problem – syphilis and gonorrhœa are world wide and increasing in prevalence. Moreover the sources of infection may be symptomless, and the gonococcus (although not so far the treponema) readily becomes resistant to chemotherapy. Vaccines would be a very useful adjunct to case-tracing and treatment together with education. A syphilis vaccine seems possible as there is evidence of cross-immunity from infection with other treponemata – but the production, safety-testing and evaluation problems will be formidable. Gonorrhœa, as a superficial infection and one where reinfection is common, looks a much less favourable vaccine proposition.

Congenital and neonatal infections fall into this category (for example rubella, cytomegalovirus infections or tetanus neonatorum) and there seems little doubt that vaccination of the mother at some appropriate stage – before conception in the case of live virus vaccines (Dudgeon 1969*b*) – is the answer. Tetanus and other infections at parturition are, of course, largely attributable to bad hygiene and this aspect needs vigorous attention.

Infections Maintained by Man and an Intermediate Host

The important intermediate hosts are snails or arthropods and measures to reduce or eliminate them provide additional weapons for control.

The snail hosts of schistosomiasis can be killed by a variety of chemicals and their breeding reduced by control of vegetation in streams, irrigation and drainage channels. Schistosomiasis is the great scourge of irrigated agriculture in Africa, parts of South America and the Caribbean. In another form, it is important in parts of Japan, China and the western Pacific. Complete control is probably economically feasible only over relatively restricted areas under good discipline. However, a good deal can probably be achieved by focal treatment with molluscicides around places where there is frequent contact with water, for example washing or bathing places. As the schistosome eggs are shed by man in urine or fæces, control must depend on a combination of snail control and treatment of the disease in man together with education and the provision of facilities for good hygiene and the avoidance of water contamination. Chemotherapy has the effect not only of curing the disease but also of reducing the numbers of eggs shed by the community. Drugs which might be cheap enough for really widespread use are coming along but it is still uncertain whether they will be acceptable for very widespread treatment under minimal medical supervision, especially of children. The possibility of vaccines is being considered but their probable nature and modes of action are still obscure. They could form an additional element in a multifac-

torial control scheme and might be of especial value in maintaining control following an initial more comprehensive programme. Many of the chemical molluscicides also kill fish and no doubt create ecological havoc in streams and other water bodies. The potential 'cost' of such ecological changes (acceptable for example on a sugar estate) might well be unacceptable if chemical control were used over very wide areas and must be carefully considered.

Mosquitoes are most important among the arthropod intermediate hosts and malaria is the most important disease in this class. The methods of control practised during the various 'eradication schemes' are well known – basically chemotherapy to eliminate parasites, and insecticides to diminish effective contact between the mosquitoes and man. Although the overall achievements have been very great in terms of the very large populations freed or largely freed of this disease, the varying degrees of success have depended largely on the behaviour of the host mosquitoes peculiar to a particular area – especially on whether they rest on the walls of houses. Whether eradication in its full sense is possible over more than limited areas remains to be seen, but obvious difficulties arise from the inevitable piecemeal approach based on political boundaries and from the potentially great adaptability of the maintaining ecosystems. A great deal of control has been achieved but great vigilance and considerable effort is going to be needed to maintain and extend it. The important difference between 'control' and 'eradication' is that the former implies very long term or even permanent expenditure of money and effort, while the latter implies a short term intensive effort followed by freedom from futher utilization of resources. This difference is of the utmost importance in planning a control policy.

Because the scale of malaria 'eradication' has transcended all previous efforts to control a single disease and because it has deployed very large quantities of chemical insecticides, this is the place to consider the possible ecological 'costs' of such measures to control one disease without any real attempt to understand possible effects on other diseases or on the environment as a whole. No reliable assessment of the latter has yet been made, the importance of the undoubted ecological effects of DDT residues remaining *sub judice* – but there is little or no doubt that fairly substantial effects have been wrought at least on other arthropod life and that whole ecosystems may have undergone change. This is not to say that it was not justified or even acceptable – but that detailed assessments are required so that the equations of desirability and overall acceptability can be better solved in future. Only one disastrous episode of epidemic disease has been described where there was at least strong suspicion that it may have been caused by malaria control measures – the epidemic of Bolivian hæmorrhagic fever (Bolivia: Hæmorrhagic Fever Commission 1965, Smith 1968*a*). Large-scale interference with the environment invariably carries risks of this sort (Smith 1968*a*) and more research is needed so that the worst hazards can be avoided.

Dengue virus is maintained (very largely or entirely) by man and mosquitoes. In its classical nonfatal although unpleasant form, the high cost of control probably could not be justified in developing countries. But dengue hæmorrhagic fever, which has caused large numbers of deaths in children in many cities of south and south-east Asia (Halstead 1966), certainly warrants control. This form of the disease appears to be an immunological catastrophe due to repeated infections with related dengue (and perhaps other Group B) viruses and is probably the compound of exceptionally high urban populations of the mosquito host, *Aedes aegypti*, and of an increase in susceptibles due to rising birth rate and a falling mortality. This form of disease could probably be greatly abated by a substantial and maintained reduction in the mosquito population (and thus a reduced infection rate). With the highly domesticated *Ae. aegypti* this is quite feasible if education and good environmental control could eliminate the mosquito breeding places which are largely domestic water containers and the prevalent urban litter of tin cans, old tyres, &c. *Ae. aegypti* has been successfully eradicated from several South American countries. However, a piped water supply to every house, eliminating the need to store water, would probably be the most valuable – although economically unattainable – single measure.

Louse-borne typhus is worth mention in this category because its epidemic form is characteristic of a large-scale break-down in hygiene, often in war. The louse can be controlled and indeed eliminated by regular washing of clothes and the bodies they cover – and in an emergency by insecticides.

Attempts are being made to develop vaccines against malaria (Neal *et al.* 1969) but success is still a long way off. Typhus vaccine and experimental dengue vaccines exist. In diseases with an immunological pathogenesis, such as dengue hæmorrhagic fever, especial care must be taken that vaccines do not aggravate rather than ameliorate the disease. Similar considerations apply to many parasitic diseases (especially helminthic

diseases such as filariasis) where the parasite does not seem to cause serious lesions until there is a well-developed immunological reaction in the host.

The elimination of susceptibles by vaccination ought to be especially effective against infections maintained in man, but as most of those with intermediate hosts are prevalent in economically poor countries, the high cost of the development, manufacture and deployment of vaccines may inhibit their use for a long time to come. But in the face of increasing insecticide resistance, cost-benefit-analysis might in the end show vaccination to be the cheapest means of control. For the present, control of this class of infection depends mainly on control of the intermediate host, and on chemotherapy where appropriate, at least in developing countries.

Zoonoses with Vertebrate Maintenance Hosts Only

The commoner and more important infections in this category are maintained either mainly in domestic animals (e.g. brucellosis, bovine tuberculosis), are transmitted to man by domestic animals (e.g. rabies), or are maintained by wild species which have close contact with man, often especially in certain occupations (e.g. leptospirosis). Control, in the case of domestic animals, depends largely on prevention (e.g. control of importation in rabies, or vaccination of dogs in enzootic areas) or eradication (as projected for brucellosis) of the infection in the animals. In the case of milk-borne infection, pasteurization or sterilization of the milk will prevent spread to man. In all these diseases, efforts should be directed primarily at reducing effective contact between man and the maintenance hosts and vaccination of man will usually be only a temporary expedient or a last resort except perhaps in certain occupational situations (e.g. against anthrax in wool-workers, or brucellosis in veterinarians). Where the host is a wild species (e.g. rats transmitting leptospirosis in sewers, canefields or ricefields) either its population must be reduced sharply (e.g. rodent control) or vaccination of man used. Where practicable, work procedures should be modified or protective clothing provided to minimize exposure.

Zoonoses with Vertebrate and Invertebrate Hosts

These infections, many of them due to viruses (Smith 1968*b*), are epidemiologically the most complicated and their complexes of maintenance hosts are potentially most capable of mutations and adaptations which may nullify control measures. However, they also offer the most possible points for attack. In all or almost all cases, eradication of the infection from its maintenance hosts is impossible, impracticable or too expensive both in money and in 'cost' to the environment. Attention must therefore be directed to immunization of man (particularly any part of the population occupationally exposed) and/or to breaking the links between man and the maintenance hosts. The hosts which are responsible for infection of man may be quite different from the maintenance hosts. For instance the maintenance yellow fever mosquito in West Africa is *Ae. africanus* but the mosquito usually responsible for urban yellow fever is *Ae. aegypti*. Birds appear to be the main vertebrate maintenance hosts of Japanese encephalitis in Japan, but pigs (as amplifier hosts) become infected, circulate virus and infect mosquitoes in close association with man (Buescher *et al.* 1959). Human epidemics can be predicted by about two weeks by monitoring infection rates in pigs (Takahashi *et al.* 1966). Thus vaccination of both man and pigs is a feasible and effective means of control in the more developed temperate and subtropical countries where the disease is seasonally epidemic. In the tropical endemic areas of south and south-east Asia, such relatively expensive means of control are hard to justify because the disease is sporadic or endemic (and thus less spectacular), the resources available for vaccination are much more restricted and they are required for other disease problems. The control of mosquito hosts, except for peridomestic species such as *Ae. aegypti*, is impossible and/or very expensive. Outside the United States, insecticides have been and are likely to be used only in special (mainly epidemic) circumstances. In spite of very large expenditure, insecticide resistance is rapidly depriving the United States of this weapon: last year the expenditure on mosquito control against arbovirus encephalitis in the State of California alone rose to over $10 million and at the end of the season the important mosquito, *Culex tarsalis*, was found (after many years of insecticide use) to be resistant to all the licensed insecticides in many areas. The ecological cost of all this activity is unknown but must have been substantial. The main answer to these infections must lie in vaccination of man when the vaccine is safe enough and the problem serious enough; and of amplifier hosts when appropriate. This should be coupled with peridomestic and urban mosquito control – as far as possible by the elimination or modification of breeding places.

Tick-borne infections (Zoological Society of London 1962) must similarly be controlled by vaccination where justified, by avoidance of tick-bite where feasible, by the reduction of tick populations by vegetational clearing or drainage to make the resting microhabitat of the ticks less hospitable, and only in exceptional circumstances by the use of insecticides.

Two other important examples are tsetse-borne trypanosomiasis and flea-borne plague. The tsetse flies which transmit trypanosomiasis can be greatly reduced in population, or even eliminated, around human habitations by vegetation clearance (which must then be maintained) or by the use of insecticides which can be justified as in Kenya for an 'eradication' campaign or possibly for creation of a barrier zone; but not for repeated use on a large scale over a long period of time. A vaccine may eventually be developed (Neal *et al.* 1969) but the problems of growing the blood forms in adequate quantities and antigenic differences among strains create serious difficulty. An effective safe vaccine would, however, have considerable application in Africa if the logistic and economic problems could be overcome.

Plague is endemic over great areas of the world but becomes epidemic only when its small mammal and flea hosts become exceptionally numerous and there is close contact with man. Urban plague is a disease associated with war and the breakdown of hygiene, especially rat control, in towns and cities. Rodent destruction and the use of insecticides against fleas provide emergency control and vaccination of man is justified in such circumstances although no very satisfactory vaccine yet exists. Under normal circumstances, however, reasonable rodent control will prevent all but sporadic cases of plague.

PROSPECTS

Vaccines

In the long run, effective vaccines can probably be provided against a great many infections but, for the foreseeable future, adequate resources seem unlikely to be devoted to their development except against diseases which are a problem in developed countries or are of such international importance (e.g. yellow fever) that the developed countries are prepared to pay for them. However, if overseas aid could be expressed in terms of vaccine research, development and production, this obstacle could be removed. This is more likely to come to pass if problems of priorities in disease control can be solved and means provided for the determination of best methods for control. Similar considerations apply to the development and production of chemotherapeutic or chemoprophylactic substances. Vaccines for man are probably of the greatest value in infections (especially respiratory or contact infections) maintained by man, and in zoonoses maintained in wild vertebrates (C E G Smith 1969). Vaccines may also be of great value in the domestic animal hosts (particularly amplifier hosts) of zoonoses.

Formidable problems remain about making new vaccines, and existing ones, safer and more efficacious (Hilleman 1969, H Smith 1969), about the precise role which they must play in the various types of infection, and about how to produce or test them. Perkins (1969) has outlined the needs of safety testing: while reliable means exist for ascertaining whether a vaccine is safe in terms of acute complications, little is known about possible long-term hazards or indeed about how to test for them. This will undoubtedly require computerized records and ten or more years of careful follow up. The sooner a start is made, the better. With regard to virus vaccines there is no doubt that, in the short term, live-virus vaccines are effective and attractively cheap both in production and administration. But no live-virus vaccine is entirely safe and we are only beginning to suspect long-term complications from them. Highly purified vaccines containing only the necessary antigen(s) are becoming technically feasible but will be relatively very expensive. The constant recurrence of economic considerations in the control of transmissible diseases must not discourage us from research, however long-term, but these considerations should be kept in mind by all concerned.

Control of Intermediate Hosts

Although much can be and undoubtedly has been done with insecticides, molluscicides and no doubt other chemicals, the cost of their use on a large scale is very high not only in money and resources but also in ecological terms. We cannot contemplate with equanimity the prospect of saturating with synthetic chemicals the huge areas of the world where infections or infestations involve intermediate hosts. However, these substances will continue to have outstanding value in man's immediate environment and in times of emergency, especially epidemics. But few things are more urgent than to find means for the control of intermediate hosts which do not involve a heavy cost to the environment. Highly species-specific insecticides might be acceptable and any used should be destined to be quickly broken down to nontoxic materials in the environment. There is hope, but not a great deal, in the use of sterile males to eliminate arthropod populations but the number of species with which this is likely to work is very limited. Further progress must come from increased study of the physiology and behaviour of intermediate hosts, and efforts on these should not be spared.

Environmental Control

In the narrow sense of urban communities and their diseases, there is little doubt that a general improvement in living standards together with sound health education will have more general success in controlling transmissible disease than a piecemeal attack on individual diseases. However,

this will be very slowly attained by the majority of the world population and the great problem is where to place priorities in improving the environment. Moreover the growth of towns (usually under bad hygienic conditions in most of the world), the rising birth rate, and the falling neonatal and infantile mortality rates favour the spread of diseases maintained by man with or without intermediate hosts, and even the development of new diseases. With the zoonoses a fair amount can be done in the vicinity of human habitations by good control of water bodies, good drainage, and clearance of scrub or forest to minimize effective contact between the maintenance hosts and man. However, large-scale changes in the environment, usually for agricultural purposes (irrigation, deforestation, &c.), should be made with caution (Smith 1968*a*) and preferably after careful research into their possible consequences for disease, as there are plenty of examples of how they have created new and sometimes very serious disease situations.

Priorities

There must be no slacking of the research efforts into how to make new and better vaccines and therapeutic substances, nor into new methods for the control of intermediate hosts (particularly those with minimal 'cost' to the environment). In addition, research on the development of methods for the evaluation of the human and economic importance of various diseases and of the benefits achievable by various means of control, emerges as a neglected area which should now receive priority. Such research might in time enable us to decide not only how best to apply existing knowledge but also where to place emphasis in research and development for the control of particular diseases in the particular circumstances of each area of the world. Research is also urgently needed on the implications of control measures against one infection on other co-existent infections, and on the effect of large scale environmental changes (such as irrigation) on the disease pattern in whole communities. These types of research are going to need a multidisciplinary approach overstepping the barriers (often substantial) between virologists, bacteriologists, parasitologists, entomologists, clinicians, sociologists and many more.

CONCLUSIONS

'In the conquest of Mount Everest anything less than 100% success is failure, but in most communicable diseases we are not faced with the attainment of such absolute goals, but rather with trying to reduce the problem to tolerable levels, *as quickly as possible*, within the limits of available resources, recognizing that each intermediate stage towards reducing the disease to an insignificant public health problem is of positive value *per se*' (Payne 1968).

Complete eradication of all (and perhaps of any) infectious diseases in the foreseeable future is probably impracticable or too expensive either in money and resources, or in environmental devastation. The advanced countries have made great strides in the control of lethal and important infectious diseases but find themselves recognizing new frontiers to conquer: infective hepatitis, dental caries, slow viruses, infections made important by the use of immunosuppressives and so on. The advances so far have been achieved over many decades with much trial and error. The developing countries start with a much more complex disease situation, with galloping population problems, widespread malnutrition and an industrial revolution. They are impatient for rapid progress and neither they nor their more prosperous neighbours can afford unnecessary and expensive errors. Indeed with the rapid increase in population movement of all types, our developing neighbours come closer and closer, not least in terms of transmissible disease (Dorolle 1968). There is thus the greatest urgency to help them solve their problems and undoubtedly the greatest contributions to health will come from enabling them to raise their general standards of living – and especially to ameliorate the related problems of population growth and of malnutrition. Both these factors play a large part in increasing the spread and severity of infectious disease (Gordon 1969). Moreover debilitating infectious diseases such as malaria, schistosomiasis, ankylostomiasis and even relatively mild febrile illnesses play an important part in impairing the productivity of their populations, especially in agriculture.

Efforts must be made to make existing knowledge of the control of infectious diseases more available and practicable in the developing countries both by finding easier and cheaper means of application and also by providing technical and financial help on a large scale. Means must also be found to promote research, development and production of all the means of control specifically needed by the developing countries. Much of this will have to be furnished by the advanced nations but they should recognize the clear self-interest which they have in doing it.

'In this age of jet planes and soon of supersonic transport, the only way of preventing the old plagues, and some new ones, from spreading from continent to continent and from country to country is to help the poorest nations of the world to reach such a level of economic and technical development that it will be possible for them to combat the evil at its source' (Dorolle 1968).

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DISCUSSION

Professor A L Banks (*Cambridge*) wished to take issue with some of the remedies proposed. As far as the developing countries and the World Health Organization were concerned, a great deal had been and was being done, particularly in the research institutes and the vaccine institutes; he did not think the picture was quite as gloomy as Dr Gordon Smith made it.

He wished that Dr Gordon Smith had touched a little more on what was probably the fundamental weakness—the lack of basic medical services to reach the people, 75–80% of whom lived in rural areas.

Dr Gordon Smith agreed with much of what had been said. He had been acutely aware for a great many years of the problem of getting doctors to work in the rural areas of developing countries. It seemed that the only solution to this was a sufficient saturation of the cities, so that doctors had to go to work in the rural areas.

It was true that there was a great deal of knowledge; much of it, though, had not been turned into a form in which it could be readily applied in the developing countries, because of the lack of trained and expert personnel. He agreed that there was a considerable amount of research going on, but even when the research had been done to produce a vaccine, for example, the impetus to take it from research to an available product at a reasonable price was generally lacking, and this was the real difficulty.

Professor L J Bruce-Chwatt believed that some new data on malaria eradication might be of interest. The latest report of WHO indicated that the global programme carried out during the past twelve years had reached about 78% of its target figure in terms of population protected. However, the remaining 22% of the programme would be more difficult to complete than anything done before. Thus in countries inhabited by about 380 million people, in tropical areas, malaria eradication had not even started and malaria control operations made little impact on the incidence of this disease.

As far as relationship between malaria control and population pressure was concerned, Professor Glass might be interested in a few figures. It had been estimated that over the past two decades deaths due to malaria decreased from 2·5 million every year to well below one million. The annual incidence of malaria before 1950 was about 250 million cases, with a fatality rate of 1%. If such incidence of malaria had been maintained through the period 1950–60 there would have been some 25 million deaths attributable to this disease, instead of about 15 million that have occurred. Thus control of malaria reduced the number of deaths by 10 million, but during that period the world population went up by 500 million.

There was little doubt that improved socio-economic conditions might decrease the amount of some communicable diseases but little could be achieved when direct improvements of the health of the community were neglected. This was the case of the famous Pearson report on aid to developing countries, in which health as a factor contributing to the progress and wellbeing of the tropical countries was sadly under-estimated.

In fact some development schemes which ignored the problems of public health could be disastrous. This might apply to the large 'man-made lakes' such as that of the Kainji Dam in Nigeria and many others. The ecological and health problems of such projects were often neglected by the governments and occasionally even by some international agencies.

Dr Gordon Smith said that he had no quarrel with anything which Professor Bruce-Chwatt had said, but he would like to take up one point and extend it slightly. It was unbelievable that an economic report could dismiss disease in the way described. The economic impact of disease, particularly in agricultural populations, was immense. The effect of malaria control in the Philippines reduced an absentee rate of 35% to negligible proportions. Many other febrile illnesses (such as those caused by viruses) were of similar economic importance, as were such other diseases as ankylostomiasis, which caused severe and chronic anæmia. The control of this kind of disease was of the greatest economic importance and of the greatest importance in enhancing food supplies. For a report on economic development completely to ignore communicable diseases was an unbelievable oversight.

Dr N M Goodman (*London*) wished to comment on smallpox eradication, the other disease which had been taken up by WHO with a view to complete eradication, in the same way as with malaria.

At first sight it would certainly seem that Dr Gordon Smith's first priority of providing cheap available vaccines would suffice; the population had to be vaccinated up to a certain level and smallpox would be eliminated. But he would support, and emphasize, Professor Bank's view that even smallpox campaigns became completely useless unless there was the basic public health organization to mount the campaign and above all to follow it up and evaluate it.

The report 'The Second Ten Years of WHO' emphasized again and again that mere elimination of, or attempt to eliminate, a communicable disease was not enough. Until there was a structure, such as the Turkish government had been trying to establish in eastern Turkey recently, of putting small health teams in the villages, attempts to eradicate infectious diseases would come to nothing in the end.

Dr Gordon Smith agreed.

A member said that there were still infectious diseases in 1970 of which the cause and the organism were unknown, particularly hepatitis. Although much could be done in this field through public health measures, until some more basic scientific knowledge of the biology of the organism was gained no logical advice could be offered either in this country or overseas.

Dr G S Nelson (*London School of Hygiene and Tropical Medicine*) said he would like to take issue with Professor Banks on the necessity for having basic health services in a country before anything could be done. This was often an excuse for delaying the progress of the eradication of quite a number of diseases in these countries.

He spoke from experience. For six years he was medical officer of health in a district in Uganda with a population of 400,000 people, where the basic health services were run by one doctor, one assistant medical officer of health and a number of medical assistants. In that area they eradicated smallpox; a prevalence of sleeping sickness of over 1,000 cases a year was reduced to one case a year; yaws, which affected something like 30% of the population, was eliminated, as were epidemics of cerebrospinal meningitis. In fact a great deal was done with a very small but devoted health service staff. It was not so much an increase in the number of personnel that was required, but increased devotion and enthusiasm of the medical personnel who worked in rural areas.

Uganda was not exceptional in achieving so much with so few doctors. For several years Dr Nelson had worked in Kenya where, again, there was a very small but devoted medical staff. In Kenya onchocerciasis (river blindness), which caused something like 10% of blindness in some of the western valleys, was totally and completely eradicated by a devoted entomologist with a small but enthusiastic group of helpers; they treated every river and stream over an area of more than 6,000 square miles, until the vector had been completely eliminated. This was a fine achievement by a very small health service. In the same country a great deal was achieved in the control of many other communicable diseases. If the tools at hand at the moment were used with determination, a major impact could be made on communicable diseases in these developing countries without waiting for a vast network of basic health services.

Miss Olga Uvarov said that one often heard what large organizations could do, yet individual efforts had in the past accomplished a great deal in some spheres of medicine. For example, when Cyprus was under British control, the dedicated work of the chief medical officer and the chief veterinary officer resulted in eradication of malaria in man and warble fly in cattle. This was done by devoted teams of people. She thought it should be recognized that dedication in a professional sense was perhaps as important as, if not more important than, these expectations from vast organizations to which every one was now looking.

Mr C P de Fonseka (*Bristol*) said he had listened to the debate with great interest. Half of his professional career was spent in Great Britain and half in Ceylon, and he had some experience of the problems under discussion because, when he held the Chair of Surgery at the University of Ceylon, he was responsible for the establishment of the clinical departments of the second medical school in Kandy, Ceylon. He agreed that it was always possible to quote examples of tremendous good being done by small bands of very devoted people. The history of the spread of scientific medicine through underdeveloped regions was full of examples. From his experience of three years as lecturer and five years in a Chair in a developing country, he would make a plea that one of the most important ways of improving things was to guide more effectively the distribution of aid. As Professor of Surgery in Colombo he had the experience once of conducting operations at the premier children's hospital, involving the removal of roundworms from obstructed intestines, and then going to sit at a committee meeting which was trying to decide where a unit for advanced intracardiac investigations, presented by Canada, should be sited. Never in his experience of over fifteen years in underdeveloped countries had he ever heard it seriously suggested that at least part of the control of hookworm in the population should be by the encouragement of the wearing of shoes.

It was necessary that priorities in the developing countries be more realistically assessed in the higher echelons of WHO and the British Council. It was wrong that substantial aid should go out to specialties like intracardiac surgery; the greatest priority was aid for the application of scientific knowledge, already established by research, to the control of bowel disease, the improvement of hygiene and water supplies, and other such necessities.

Professor Banks in reply said he would be the last man in the world to denigrate the efforts of dedicated people. The provision of basic medical services was a matter for governments. The ideal was one doctor to every 5,000 people, which was not yet reached in any developing country rural area that he knew of.